Technical issues of grid connected renewable energy sources – A New Areas of Research

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Abstract

With its ever-growing energy demand, the world has a great potential to utilize renewable energy resources towards a more secure energy future. Renewable energy will play an important role in meeting high-energy demand growth and in addressing environmental concerns from the increase in fossil-fuelled power generation. However, the potential for a large-scale shift from the use of fossil fuels to renewable energy for electricity generation remains a highly debated issue in many countries. This is not without reason, as large-scale implementation of renewable energy will pose significant challenges to legacy power systems due to temporal fluctuations, geographical dispersion of renewable energy sources and inadequacy of the existing power grid.

The paper will focus on potential new areas of research with relation to technical constrains of integrating renewable energy sources into the grid and analyze the different measures, strategies and policies used by different countries and governments to address the issues related to the grid connected renewable energy systems. In addition, existing barriers that limit the large-scale deployment of renewable energy sources, as well as possible solutions to overcome them.

1 Introduction

Increasing consumption of fossil fuel to meet current energy demands has generated a resurgence of interest in promoting renewable alternatives to obtain the developing world's growing energy needs [1, 2]. Residential and industrial needs for centuries which has been satisfactorily supported by traditional power generation, is failing due to environmental and economic concerns[3]. Based on IPCC report, the main reason behind alarming environmental phenomena, such as global warming and sea level rising is increasing concentration of CO2 and other greenhouse gases (GHG) is [4]. A major source of CO2 emissions in the world, is the electricity supply sector, accounting for about 37% of global CO2 emissions, which may constantly rise in the future [5, 6]. Increasing use of fossil fuels has initiated global warming by carbon dioxide; hence, renewable promotion of clean energy is eagerly required [7].

Therefore, driving force in the effort to sustain the earth's natural resources and to improve the users' quality of life has become Renewable energy (RE). RE such as wind or solar energy which produces no negative impacts during conversion process like the emission of hazardous substances can be defined as a free source of sustainable energy. Thus, goals for the development of RE have set by recent eco-consciousness agendas in many countries, specifically for its conversion and efficient generation to a consumable form of energy and its commercialization in the market[3]. Renewable energy sources (RES) which supplies 14% of the total world energy demand [8], includes biomass, hydropower, geothermal, solar, wind and marine energies. The renewable that also called alternative energy sources, consider as the primary, domestic and clean or inexhaustible energy resources [9, 10]. RESs is expected to increase the share significantly (30–80% in 2100) [11].

Renewable technologies are considered as clean sources of energy, by optimal using of natural resources. RE takes advantages of minimizes environmental impacts, produce minimum secondary wastes and are sustainable based on current and future economic and social societal needs [12]. Hence, an excellent opportunity for mitigation of greenhouse gas emission and reducing global warming has been provide by applying renewable energy technologies through substituting conventional energy sources. Therefore, there is a need for methods and tools to measure and compare the environmental impacts of human activities for various products for Sustainable development [13]. It has long been recognized that excessive fossil fuel consumption will not only lead to an increase in the rate of diminishing fossil fuel reserves, but it also has a significant adverse impact on the environment, by increasing the health risks and the threat of global climate change [14].

Changes towards environmental improvements especially in developed countries are becoming more politically acceptable. Society is moving towards slowly while seeking more sustainable production methods, conservation of native forests, reduction of greenhouse gas emissions, waste minimization, reduced air pollution and distributed energy generation [15]. Nevertheless, higher conversion costs, limited locations, environmental impacts, and other factors put barriers to such development. Though, governments, researchers, and stakeholders should work together to enhance the conversion efficiency of RE, develop advanced storage technologies, control distribution efficiency, and commercialize the use of RE ultimately. Many initiatives all over the world have addressed the efficient use or replacement of traditional energy resources, such as crude oil, coal, and natural gas due to the rapid depletion of these sources. Renewable energy sources provides managerial insights to governments, researchers, and stakeholders for the initiation of renewable energy use. Barriers like the conversion cost, location constraints, complex distribution networks and other considerable barriers is identified for the generation and utilization of REs. These barriers is suggested to be resolved through the involvement of governments, researchers, and stakeholders in the development of RE [16].

2 Barrier and challenges of Grid connected RES and possible solutions

The importance of a sustainable and efficient energy concept is evident[17]. The integration of the renewable energy sources (RES) in to the power grid has attracted a lot of researchers. Thus, building a hybrid system has become very crucial [18, 19]. The use of RES is one of the crucial components of the sustainable development, giving rationale economic, ecological and social effects. Despite that, it is commonly known that the RES implementation within the electric power system is a new challenge; such implementation has constraints and can cause some perturbations [19, 20]. Due to the intermittent nature of the power generation by the RES, concerns about the stability of power system has been raised and hence RES is a potential source of power quality disturbances of the future power grid[18, 21].

Although RES systems have several appealing factors, there exists a trade-off point between the benefits of RES and the potential adverse grid effects at transmission and distribution levels. Most RES are location specific[22]. Therefore, renewable-generated electricity may need to be transported over considerable distances. The certain RE sources lack the flexibility needed to deal with certain aspects of power system operation, in particular balancing supply and demand. There are also constraints with regards to very short-term system balancing[22]. Ref [19] presented some of the constrains on integrating RES in the power grid, such as:

- Unfavorable effect on voltage and reactive power regulation

- Changes in the value of short-circuit power.
- Negative effect on power system stability in short circuits.
- Unfavorable effect on electric power protection devices.
- Voltage fluctuations in point of common coupling (PCC)
- Voltage unbalance
- Flicker effect
- Harmonic and inter harmonic voltages and currents.

Other challenges raised by other authors were with regards to scability and timing[32]. A study in paper [17] mentioned that the growing installations of RES require a coordinated effort from the planning stage all the way down to the electronic devices used for power generation, distribution, storage and consumption. This means that the RES can't be considered as an isolated node of the energy network: producers, consumers and storage systems must rather be an integral part of the grid that automatically allows for an optimization of the available resource usage and balancing with current demand.

Other studies [22] mentioned that the expected disruptions, which grid-connected RES systems might introduce to the grid network, include voltage rise effect, voltage flicker, harmonics, degrading minimum fault current; however, as the injected power of grid-connected RES increases, the power quality and overall system's reliability decline. This decline may be observed from the sustained interruptions [22].

Refs. [23, 24] focused on the major difficulties of the PV systems which may pose some adverse effects to the system, such as overloading of the feeders, harmonic pollution, high investment cost, low efficiency, and low reliability, which hinder their widespread use[24]. Moreover, variations in solar irradiation can cause power fluctuation and voltage flicker, resulting in undesirable effects on high penetrated PV systems in the power system, some control methods, such as Maximum Power Point Tracking (MPPT) can be used to improve the efficiency of PV systems. While another research paper [23]explained that the extension costs are significant factors for integrating RES into an existing electricity network.

Other research papers,[22, 25] considered the voltage rise effect as one of the issues that would surface as a result of increasing RES interconnection given the low demand season. Voltage rise can be handled through the control of power factor, reduction of high-voltage/medium-voltage (HV/MV) substation voltage setting, and ring-operated distribution network with respect to the RES interconnection

Another studies conducted by Kanjiya and Papathanassiou [18, 21] mentioned that the RES may cause voltage flicker as a result of the surrounding and environmental changes which would have resulted in a significant voltage change on the feeder. In case of wind and solar energy systems, the output fluctuates as the intensity of the wind's current and sun's radiations changes. These voltage flickers are also caused by switching operations in the RES installation usually the start or stop operations of equipment.

Another study [18] illustrates that in today's power system, the power generated by the conventional power generators follows the load demand. Whenever load demand changes they can effectively keep the systems stability by providing the differential power from its stored energy in high rotor inertia. However, by the integration of distributed RES without any inertia, the load has to dynamically follow the power generation to keep systems stability.

To achieve demand-side management or demand response, authors of other studies [26-31]have proposed different solutions. While the authors of [18] considered that the previous methods have their own pros and cons ;however, no method is able to match the load demand to the power generation in real-time with substantial penetration of intermittent RES. Therefore, they proposed a new approach to demand-side management based on electric spring concept was proposed.

2.1 POSSIBLE SOLUTIONS TO TECHNICAL ISSUES

For the promise of an alternative energy source to be achieved, it must be supplied in the time frame needed, in the volume needed, and at a reasonable cost. Many alternatives have been successfully demonstrated at the small scale but demonstration scale does not provide an indication of the potential for large-scale production. This difference between "production" of alternative energy and "extraction" of fossil fuels can result in marked constraints on the ability to increase the production of an alternative energy source as it is needed.

Besides, intermittency, storage and capacity factor [32, 33] were other challenges to RES. RES produce only intermittently as the wind blows or the sun shines. Integration of these sources into the current power grid creates challenges of balancing availability and demand. One indication of intermittency challenge is the capacity factor, or the average percentage of time in a year that a power plant is producing at full rated capacity, so the integration of the RES to the grid would need large quantities of conventional back up power and huge energy storage to compensate for natural variations in the amount of power generated depending on the time of day, season and other factor. The development of wind and solar-power electricity also requires additional infrastructure where wind and solar electricity must be generated where the best resources exist, which is often far from population centers.

3 Energy Policy

Since 1990, energy policies and regulations have been changed dramatically around the world due to economic, environmental, security and social concerns. Therefore, many of the changes have been a profound influence on renewable energy both from direct and indirect policies. Direct policies are explicitly designed to promote renewable energy while indirect policies influence incentives and barriers for renewable energy [34]. Overall, renewable energy promotion policies comprised of three main categories:

- Price setting and quantity- forcing policies, which mandate prices or quantities
- Investment cost reduction policies, which provides incentives in the form of lower investment cost
- And public investments and market facilitation activities which offer a wide range of public policies that reduce marker barriers and facilitate or scale up renewable energy markets[34, 35].

In general, Price setting and quantity- forcing policies include US public utility regulatory policies act (PURPA), electricity Feed in Laws, Competitively bid as well as RE obligations, RE portfolio standards (RPS), renewable energy green certificate. Moreover, cost reduction policies cover subsidies and rebates, tax relief, grants and loans. From public investments and market facilitation activities viewpoint, public benefic funds, infrastructure policies and government procurement are the most prominent initiatives.

One of the recent targets which covers all the above three categories is national renewable energy target which concentrates on the aggregate energy production of an entire country or group of countries. Targets may specify total primary energy from renewables or minimum renewable energy shares of electricity generation. Many countries have adopted national renewable energy targets. The European Union has adopted a target of 22% of total electricity generation from renewables by 2010. Japan has adopted a target of 3% of total primary energy by 2010. The recent regulatory proposals in United States would require 10% of electricity generation by 2020. China and India are pioneers among developing countries to propose renewable energy targets. India has proposed that by 2012, China has a similar goal of 5% by 2010. Other countries with existing or proposed targets are Australia, Brazil, Malaysia, and Thailand [35].

In this context, governments have taken specific measures to scale up renewable energy technologies (RE technologies) which leads to improve energy security, support economic development and address climate change and environmental concerns.

In terms of energy security, availability, affordability and sustainability of energy supply are in nexus of overall energy security. The increase of RE technologies has high priority within a comprehensive strategy towards more sustainable economic growth and has been labeled "green growth" by OECD [Organization for Economic Co-operation and Development, 2011]. As an example, the Green Development section of China's 12th Five-Year Plan (FYP, 2011-15) highlights the country's aspiration to move towards a greener economy. The Green Development theme determines six strategic pillars: respond to climate change, strengthen resource saving and management, develop the "circular economy", enhance environmental protection, promote ecosystem protection and recovery, and strengthen systems for water conservation and natural disaster prevention.

In terms of economic development, several RE market leaders (including Germany, Denmark and Japan) have established industrial and economic development objectives for support of RE technologies [36, 37]. These countries created many strong industrial clusters and increased domestic markets by formulating innovative policies and facilitating investment conditions for RE technologies, including solar and wind.

In terms of environmental concern, RE technologies decrease the amount of CO_2 produced by substituting for fossil fuels used in producing electricity and heat and in transport. This policy can reinforce the development of renewable electricity by consideration of the lifecycle emissions of a number of RE technologies in the power sector. In addition, the results of several life-cycle assessment studies illustrate that all renewable power generation technologies have significantly lower life-cycle CO_2 emissions than fossil-based technologies. In 2008, almost half of the CO_2 savings due to RE technologies stems from the OECD, and more than a third of all savings from China [36, 37]

3.1 SUPPORTING POLICIES

Specifically, three types of support policies applied for deploying renewable electricity on a large scale are feed-in tariffs (FITs), tradable green certificates (TGCs) in conjunction with quota obligations, and tenders [38]. Feed-in tariffs (FITs) support the generator of renewable electricity a certain price per kWh at which electricity is bought, commonly 20 years. This policy and similar ones are initiated in Germany and other European countries in the 1990[35]. It sets a fix price for utility purchase of renewable energy. Other countries in Europe with renewable energy electricity feed in laws include Denmark, France, Greece, Italy, Portugal, Spain, UK and Sweden. Although originally meant to be the only remuneration to generators, some later FITs provide a premium. Generators sell their electricity on the market and receive a premium on top. Some governments have put annual caps on the amount of capacity that can benefit from FIT support in a certain time period. The most recent novel tool regarding FITs is the breathing cap, which was initiated for solar PV in Germany. The tariff digression is connected to the deployment in the year before [38]. Certificate systems are based on its greenness. The power is sold on the normal market. In addition, renewable generators can sell a certificate that represents a certain amount of renewable electricity that they generated. A separate market is established for these certificates. Certificates are sold to large consumers or retailers of electricity that are obliged to buy a certain number of these certificates [38]. Under a tendering scheme, a regulatory authority states the installment of a certain capacity of a given technology or suite of technologies. For designing a project, first of all, the price at which the project developers are willing to develop the project can be determined. Tenders commonly contain specific requirements (e.g. shares of local manufacturing, details of technological specifications, maximum price per unit of energy). The lowest bidder is selected and implements the project [38]. Also, tax incentives, direct cash grants and rebates are other mechanisms which have been employed mainly in the United State to scale up renewable electricity [38].

Ultimately, many developing countries have explicit policies to extend electric networks to large shares of rural populations that are unconnected to power grids. These policies may also provide explicit government financial support for renewable energy in these areas. The pioneer countries with such policies include Argentina, China, India, Morocco, the Philippines, South Africa and Sri Lanka. A remarkable initiative under this policy is energy service concessions which enable the government to select one company to exclusively serve a specific geographic region covering all customers who request service [35].

4 Conclusion

The use of RES is one of the crucial components of the sustainable development, giving rationale economic, ecological and social effects. Conversion cost, location constraints, complex distribution networks and other considerable barriers is identified for the generation and utilization of REs. These barriers is suggested to be resolved through the involvement of governments, researchers, and stakeholders in the development of RE. The certain RE sources lack the flexibility needed to deal with certain aspects of power system operation, in particular balancing supply and demand. Many alternatives have been successfully demonstrated at the small scale but demonstration scale does not provide an indication of the potential for large-scale production. Governments have taken specific measures to scale up renewable energy technologies which leads to improve energy security, support economic development and address climate change and environmental concerns. Specifically, three types of support policies applied for deploying renewable electricity on a large scale i.e. feed-in tariffs (FITs), tradable green certificates (TGCs) in conjunction with quota obligations, and tenders.

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